Antennas 101

“Don’t Be a 0.97 dB Weakling!”

Ward Silver N0AX

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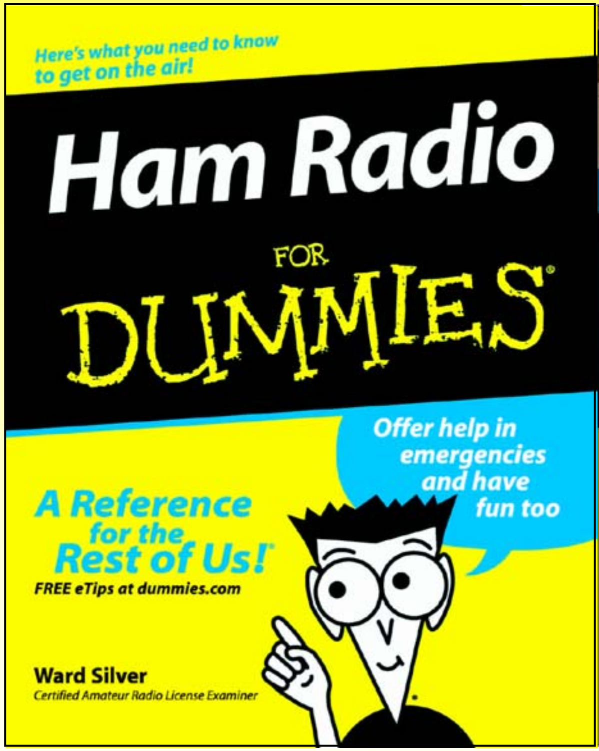
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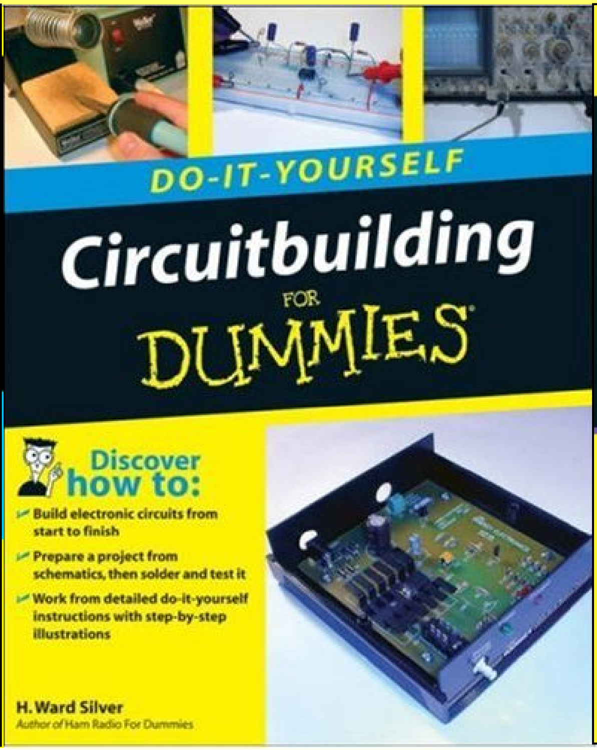
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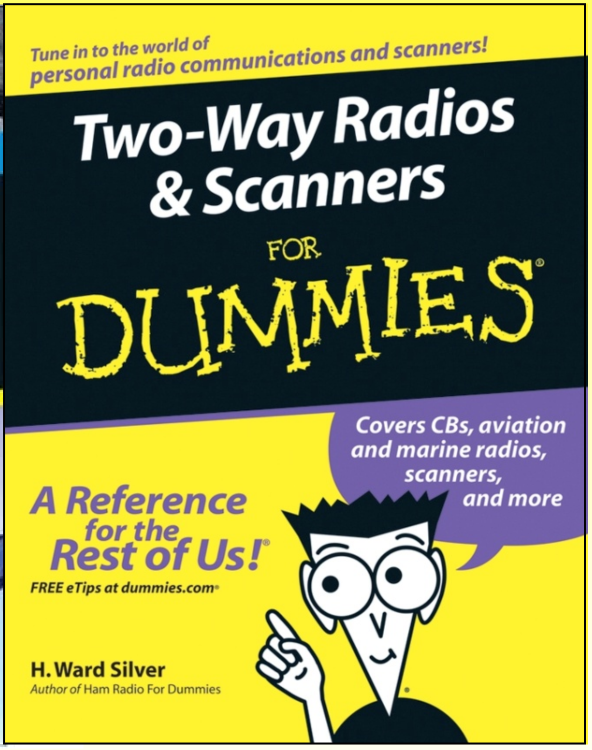
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Overview

Overview

- Highlights of ARRL course EC-009
- Basic Antennas: Ground Plane / Dipole
- How Gain and Nulls are Formed
- How Phased Arrays and Beams Work
- Loop Antennas

Antenna Design & Construction

ARRL EC-009

- 25 hours (plus projects) over 8 weeks
  - adds transmission line and practical considerations
- *Simple and Fun Antennas for Hams*
- Mentor assigned to help each student
- Costs $65 for ARRL members
- Good prep for Antenna Modeling, EC-004

The Basics - 1

- Antennas radiate (or receive) because electrons are moving (or are caused to move) back and forth in their *elements*
- Electrons move because of and parallel to electric, or "*E-fields*"
- Radio or *electromagnetic* waves are both an E- and H- (magnetic) field

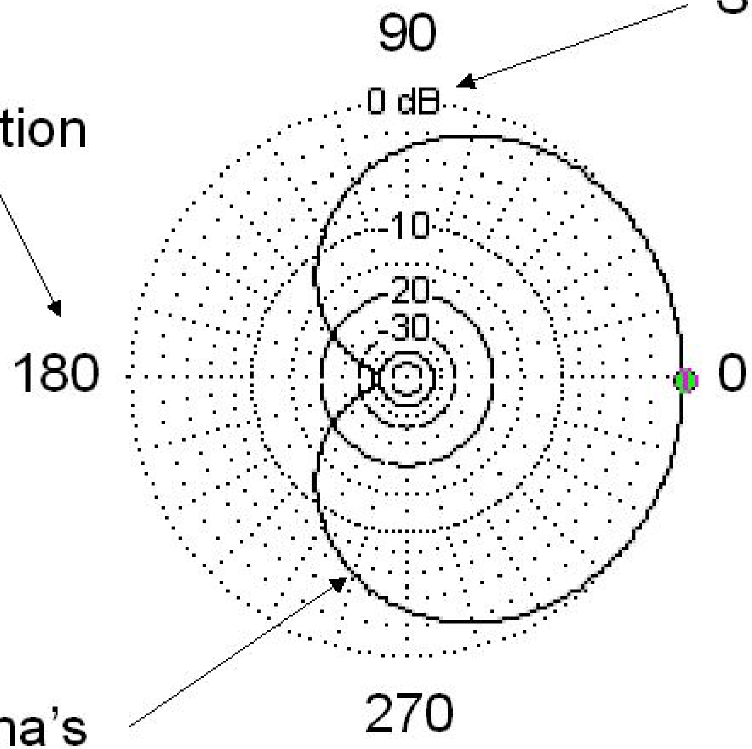
The Basics - 2

- The orientation of the E-field determines the *polarization* of the wave because that’s what makes the electrons move (current)
- Antennas transmit & receive radio waves in the same way
- The *radiation pattern* shows how antennas distribute energy in space

The Basics - 3

- deciBels (dB) = 10 log (power ratio)
- Impedance = ratio of Voltage to Current
- Feedpoint - place where power is applied

The Basics - 4



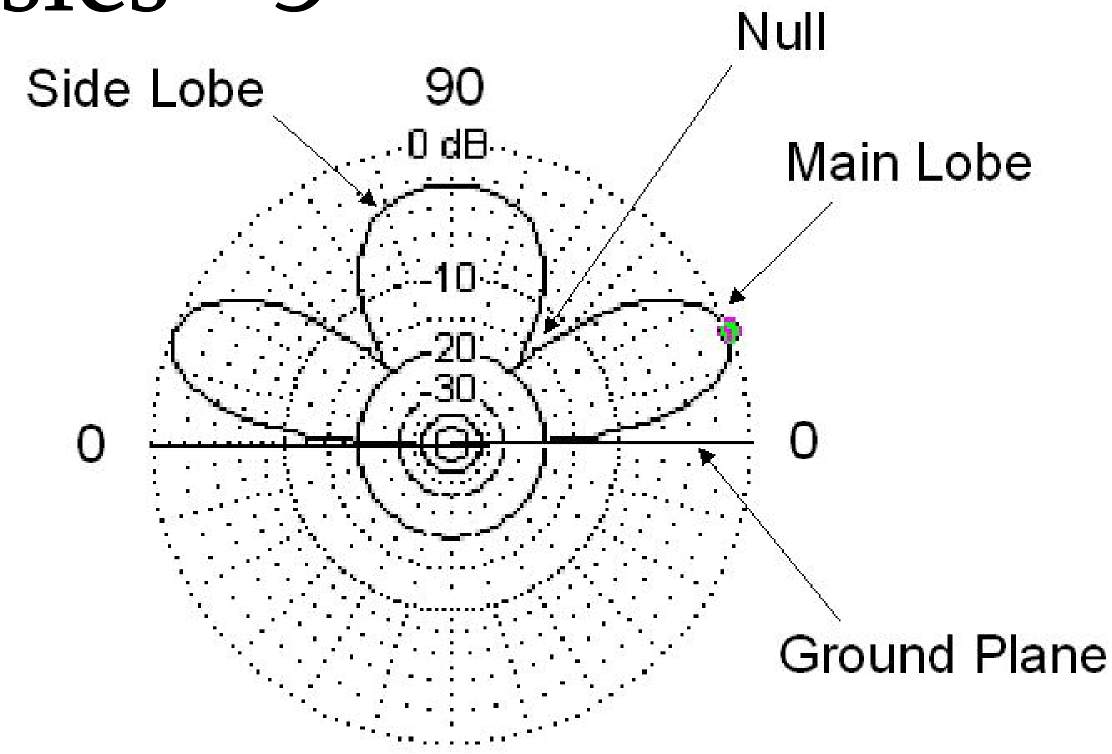
Scale for Signal Strength

Direction

Antenna's Signal Strength

Azimuthal Pattern

The Basics - 5



Elevation Pattern

The Basics - 6

- Front-to-Back, Front-to-Side, and Front-to-Rear ratios
- Beamwidth - angular width of main lobe
  - Angle between the two points at which power is ½ that at the peak (-3 dB points)

The Basics - 7

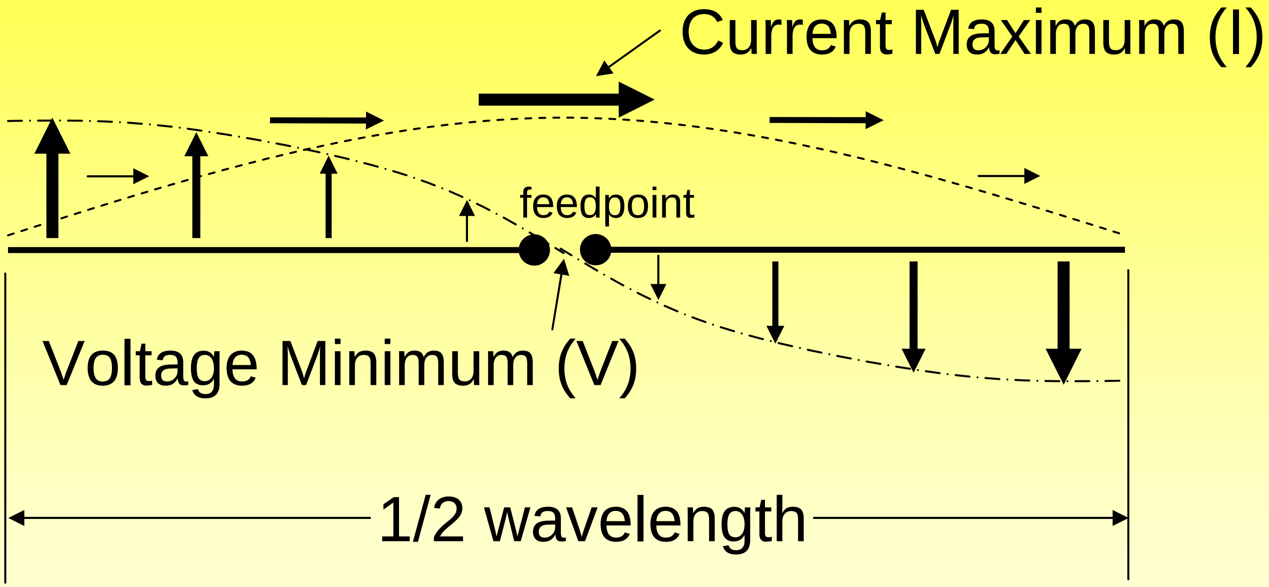
- Gain is a relative measure of effectiveness
- Gain is always *with respect to a reference*
    - dBi (isotropic), dBd (free-space dipole)
    - Dipole has 2.2 dBi gain
    - Ground plane has equivalent gain to dipole
    - 3-element Yagi may have up to 5 dBd gain

QUESTIONS??

The Dipole - 1

- Oldest and simplest form of antenna
- Similar to a vibrating string's fundamental
- Wherever it's excited…
  - Current maximum in the middle
  - Voltage maximum at the ends
- Pattern repeats every 1/2-wavelength
  - Direction or amplitude is reversed

The Dipole - 2



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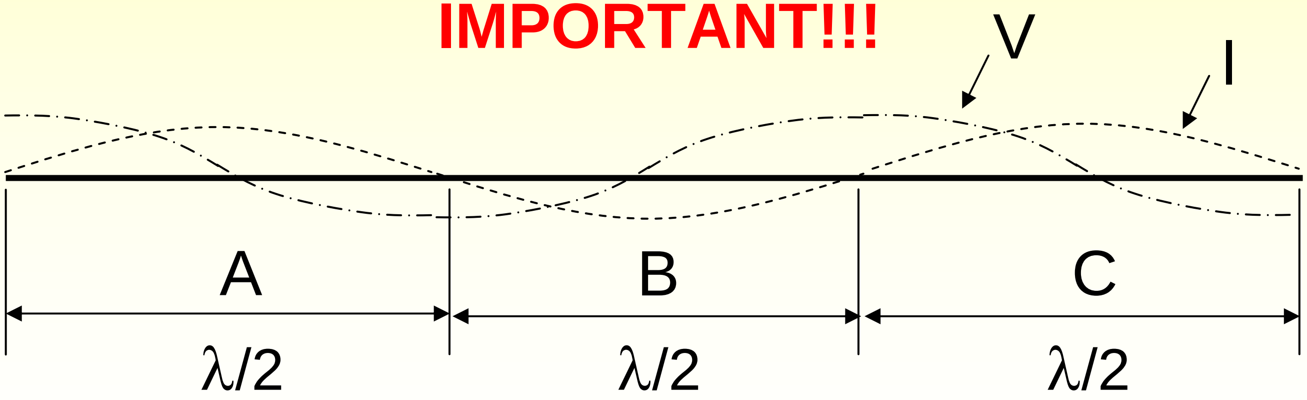


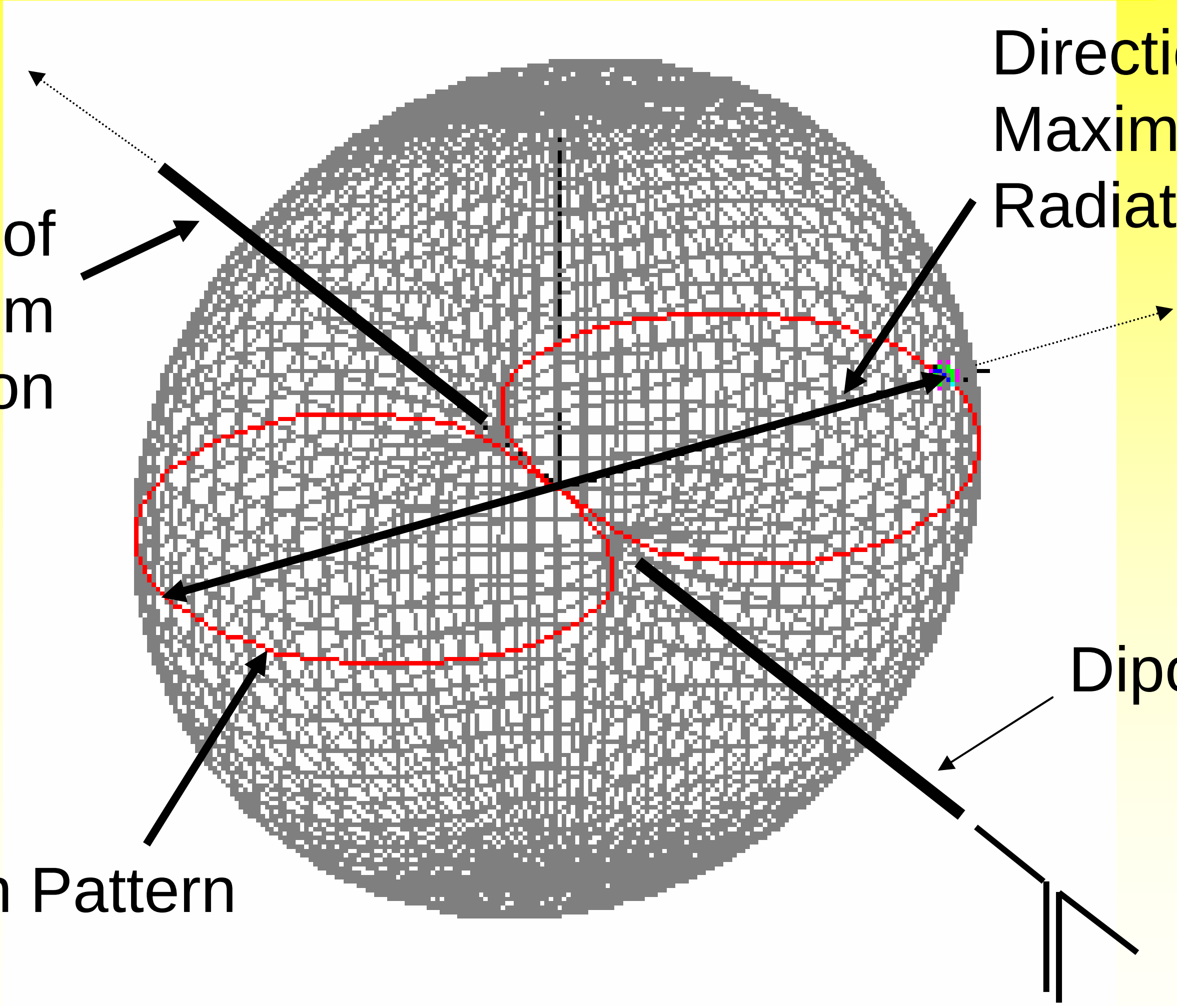
The Dipole - 3

- *Free-space* 1/2-wavelength (λ)
  - – λ = c / f or 300 / f in MHz
- *Length-to-diameter effect*
  - – makes the antenna a little longer *electrically*
  - – the “fatter” the conductor, the shorter it must be to act as an electrical 1/2 λ
  - – length in feet = 468 / f in MHz (accounts for the l-to-d effect)

The Dipole - 4

- Radiated energy is strongest *perpendicular* to an electron's motion
  - electrons move along the length of a dipole
  - radiation strongest broadside to the dipole
- Feedpoint impedance varies with position
  - High at the ends and low in the middle
  - Resonance – Feedpoint impedance all resistive, no reactance

The Dipole - 5



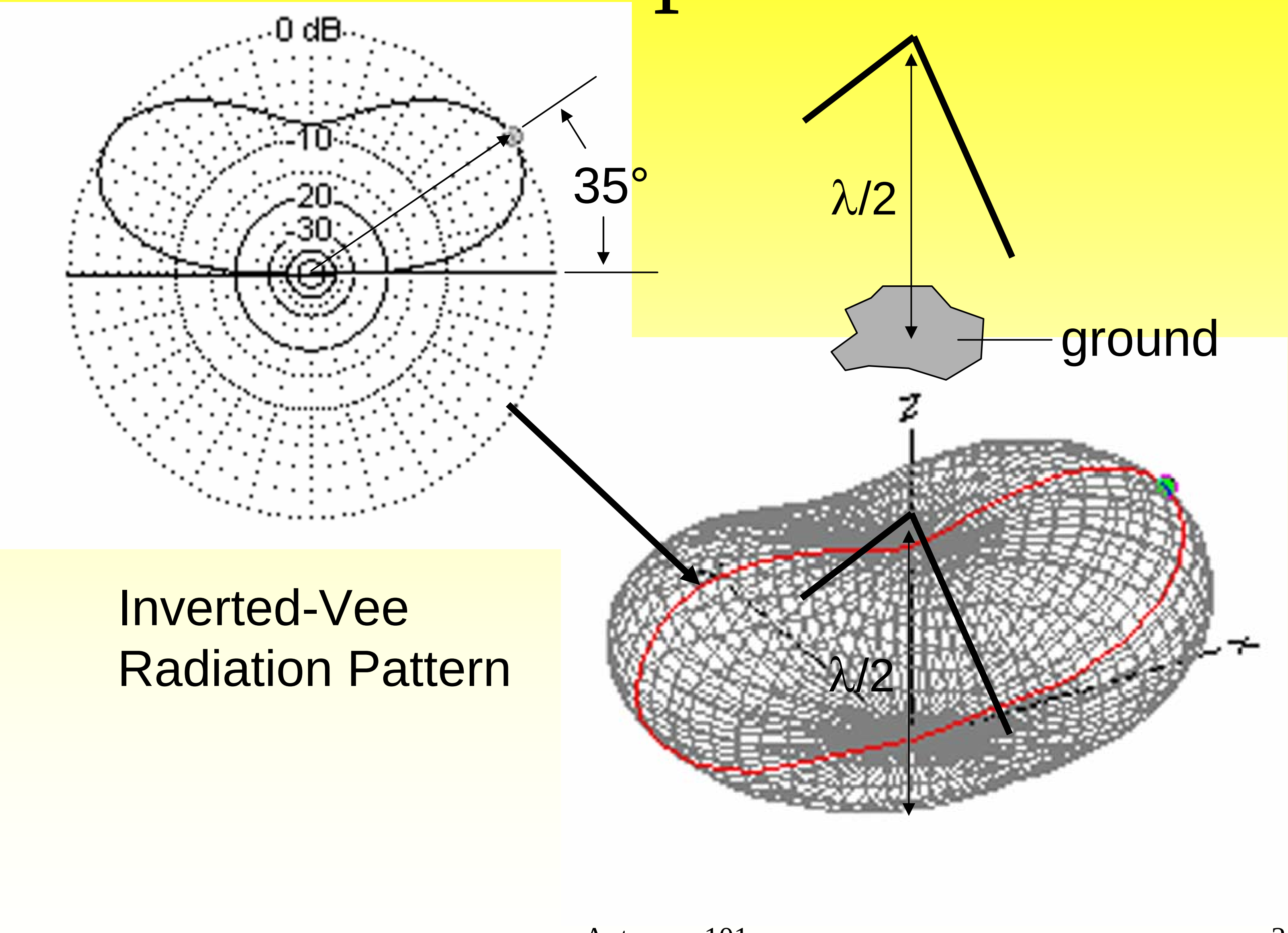
Directions of Minimum Radiation

Directions of Maximum Radiation

Dipole Axis

Radiation Pattern

The Dipole - 6



Inverted-Vee
Radiation Pattern

The Dipole - 7

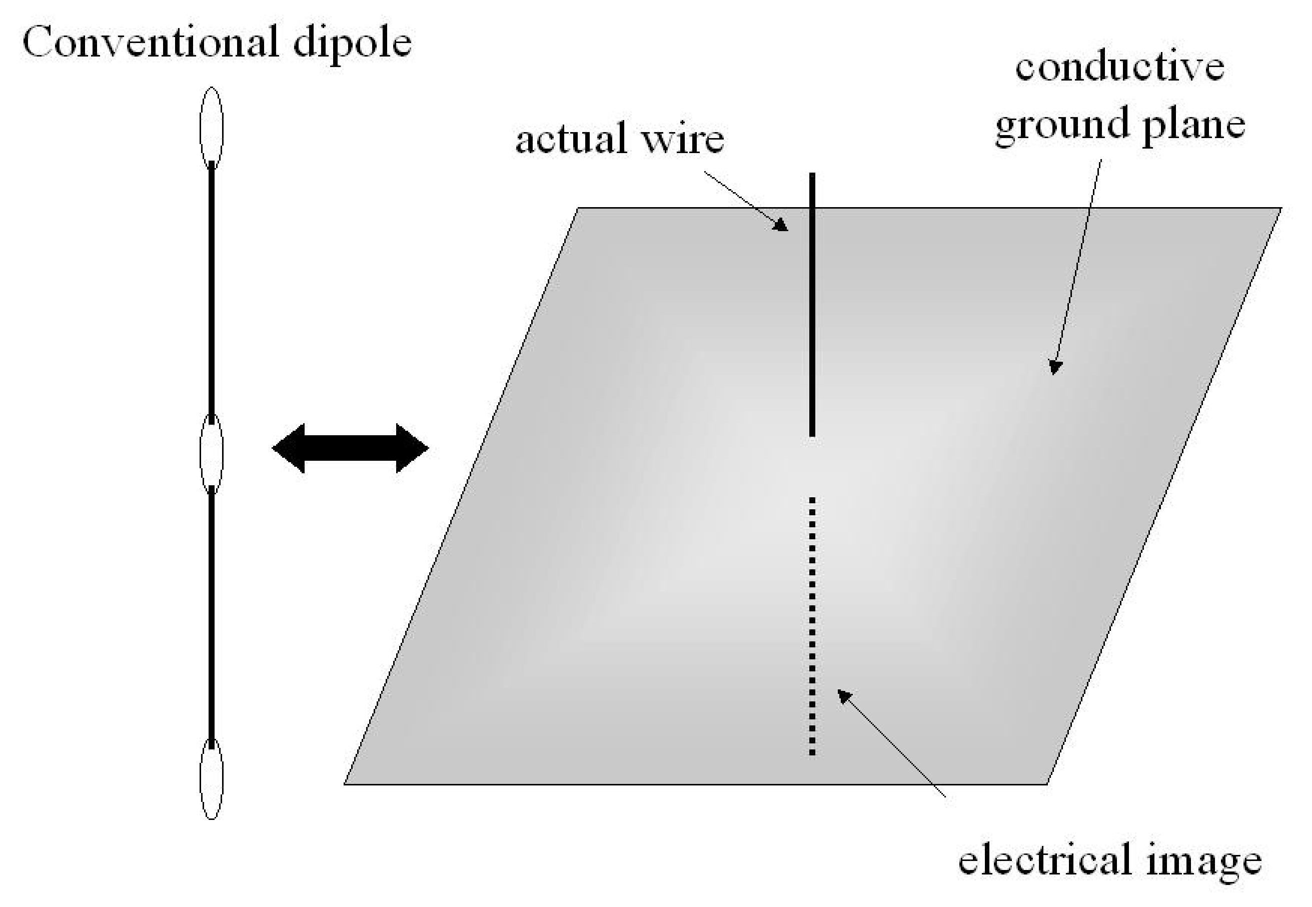
- Inverted-Vee is a “bent” dipole
- Radiation pattern adds the effect of *ground gain* from reflections
  - Can add as much as 6 dB over free space
  - Free-space gain best comparative measure
- Ground gain varies with height and with ground conductivity

QUESTIONS??

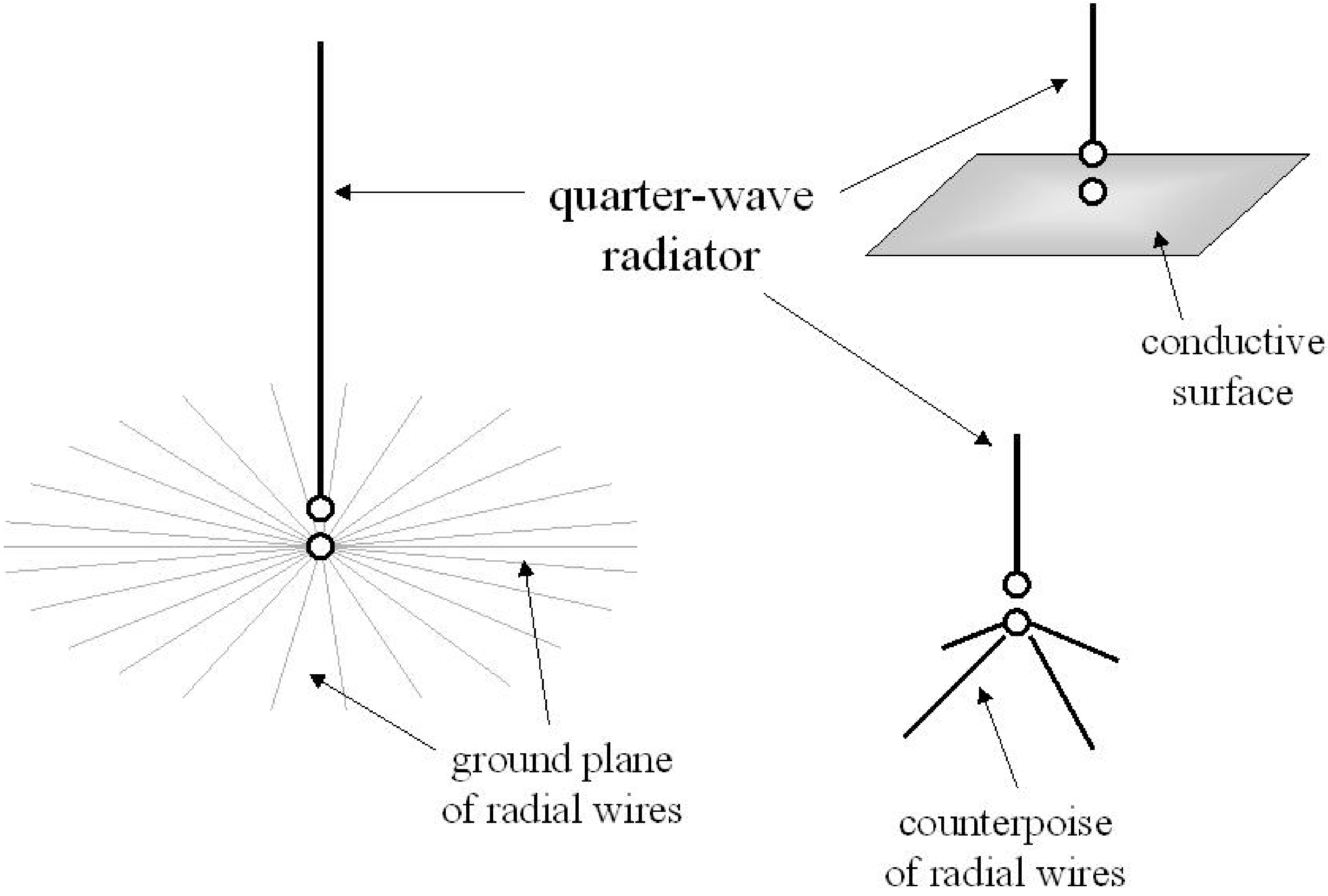
The Ground Plane - 1

- Start with a vertical dipole in free-space
- Cut off one half of the dipole
- Replace the missing half with a *ground plane* or *counterpoise*
- *Omnidirectional* if oriented vertically
- Also called a *monopole*

The Ground Plane - 2

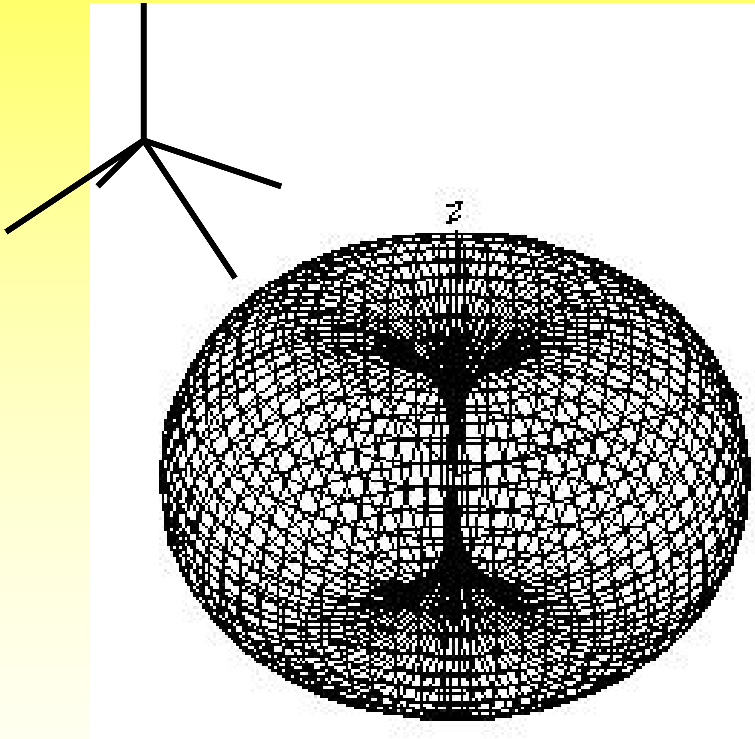


The Ground Plane - 3



The Ground Plane - 4

- Equal radiation broadside
- Nulls along the axis



The Ground Plane - 5

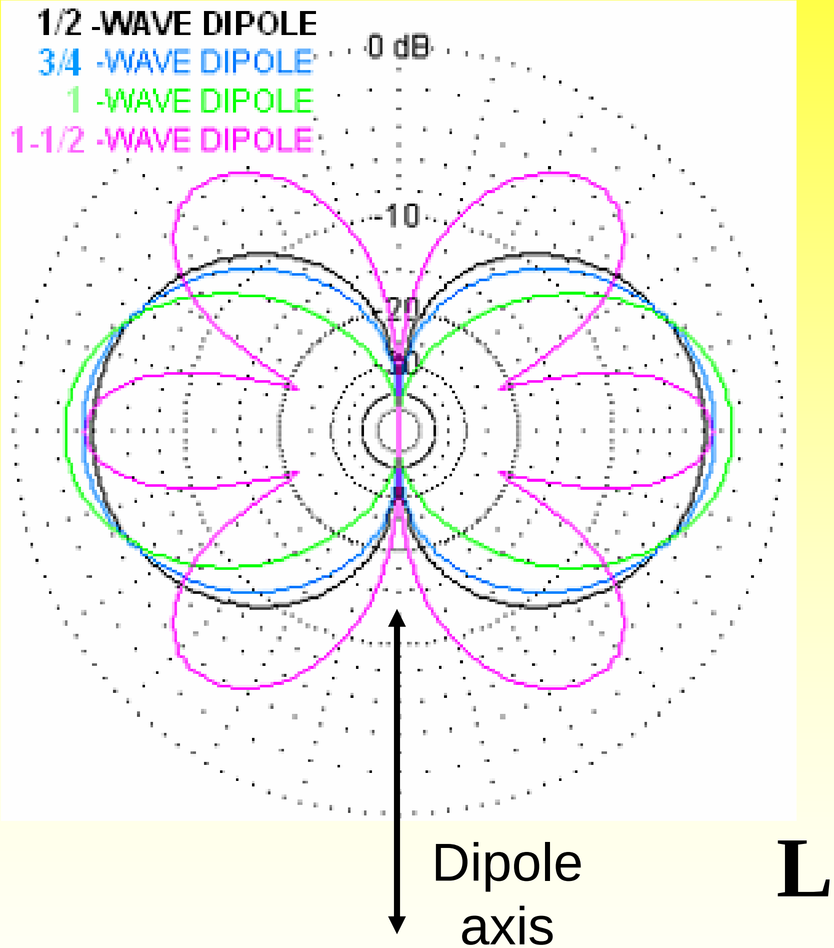
- Length (ft) = 234 / f (MHz)
  - – 231 / f if #14 wire used, - 221 if 5/8” tubing
- Feedpoint impedance approx. 35 Ω
  - – if radials used, sloping increases feedpoint impedance
  - – approximately 45° of droop gives best match
  - – halfway between dipole (72 Ω) and ground plane (35 Ω)

QUESTIONS??

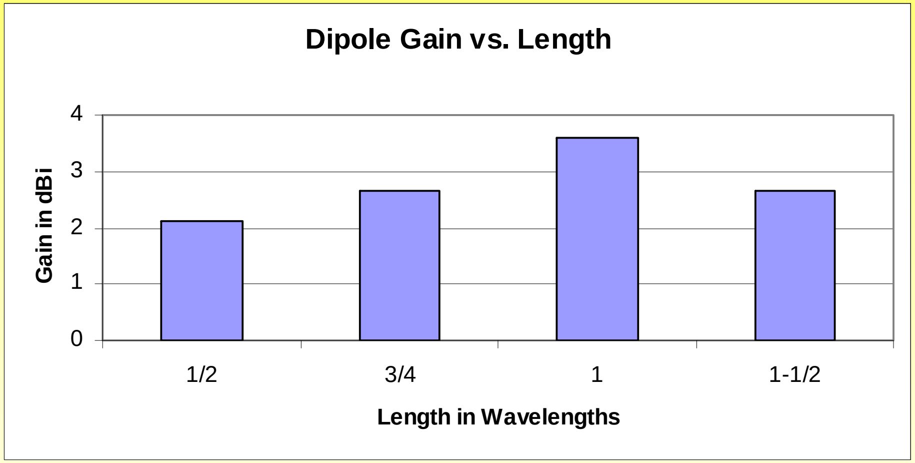
Antennas with Gain - 1

- Gain is obtained by “directing” more energy in some directions
- Gain is created by arranging currents so that their radiated fields add together
- Current can be added in separate elements, by folding or bending, or by simply lengthening a single element

Antennas with Gain - 2



Dipole axis

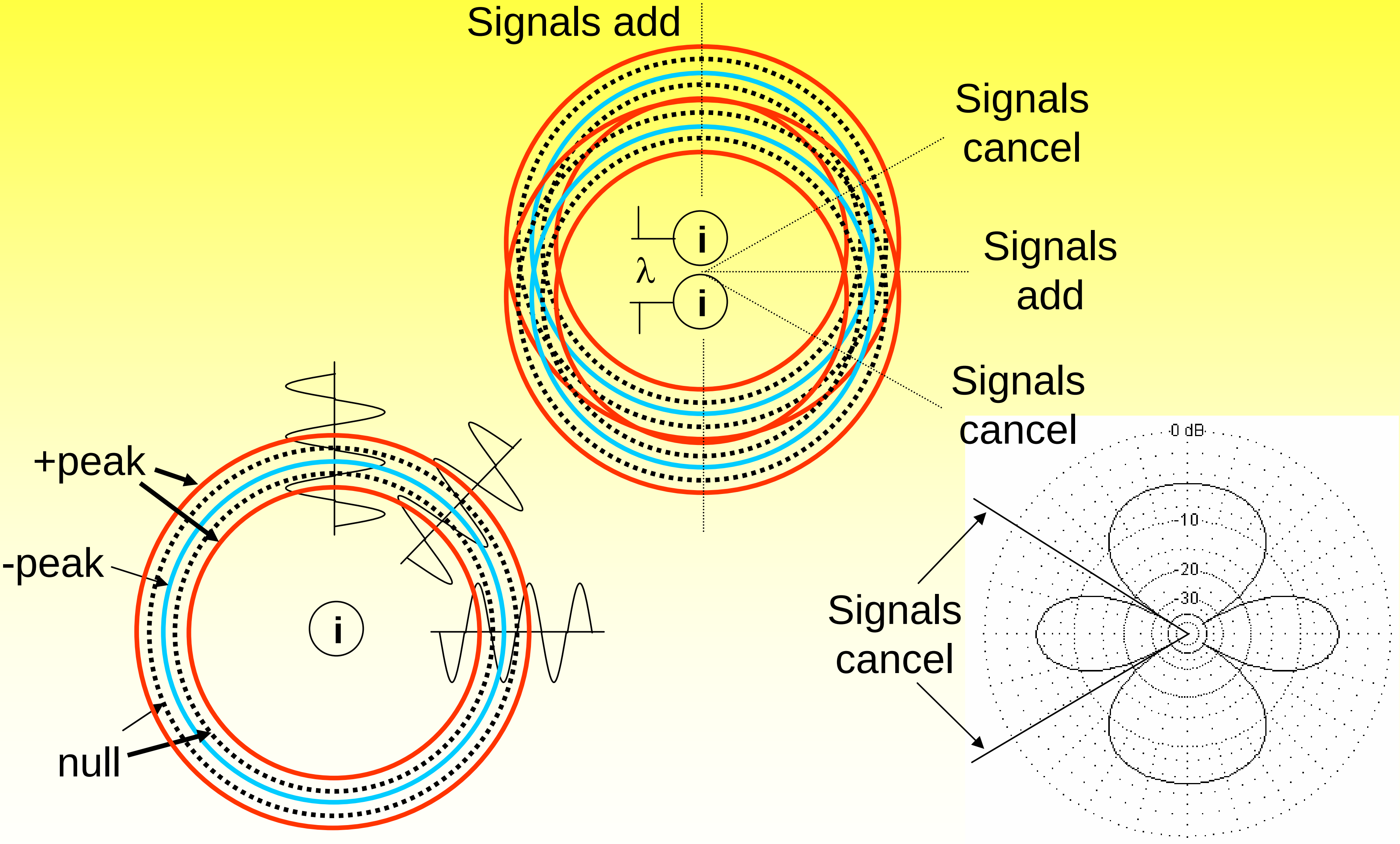


Lengthening the Dipole

Antennas with Gain - 3

- Fields from currents along the antenna can reinforce each other
  - reinforcement at large distances (>>λ)
  - this is the *far field*
- Reinforcement may occur at angles far from broadside
- Reinforcement: *constructive interference*

Antennas with Gain - 4



Signals add

Signals cancel

Signals add

Signals cancel

+peak

-peak

null

Signals cancel

Antennas with Gain - 5

- Reinforcement for gain also causes destructive interference, creating *nulls*
- Nulls are good, too!
  - Avoid interference (both to and from)
  - Improve signal-to-noise ratio in desired directions
- Adding elements also creates gain
  - E-fields can add or cancel

QUESTIONS??

Phased Arrays - 1

- *Array* - multiple antenna elements
- *Phased* - pattern created by phase differences in each element (all driven)
- *Broadside* - maximum radiation perpendicular to the plane of the array
- *End-Fire* - maximum radiation in the plane of the array

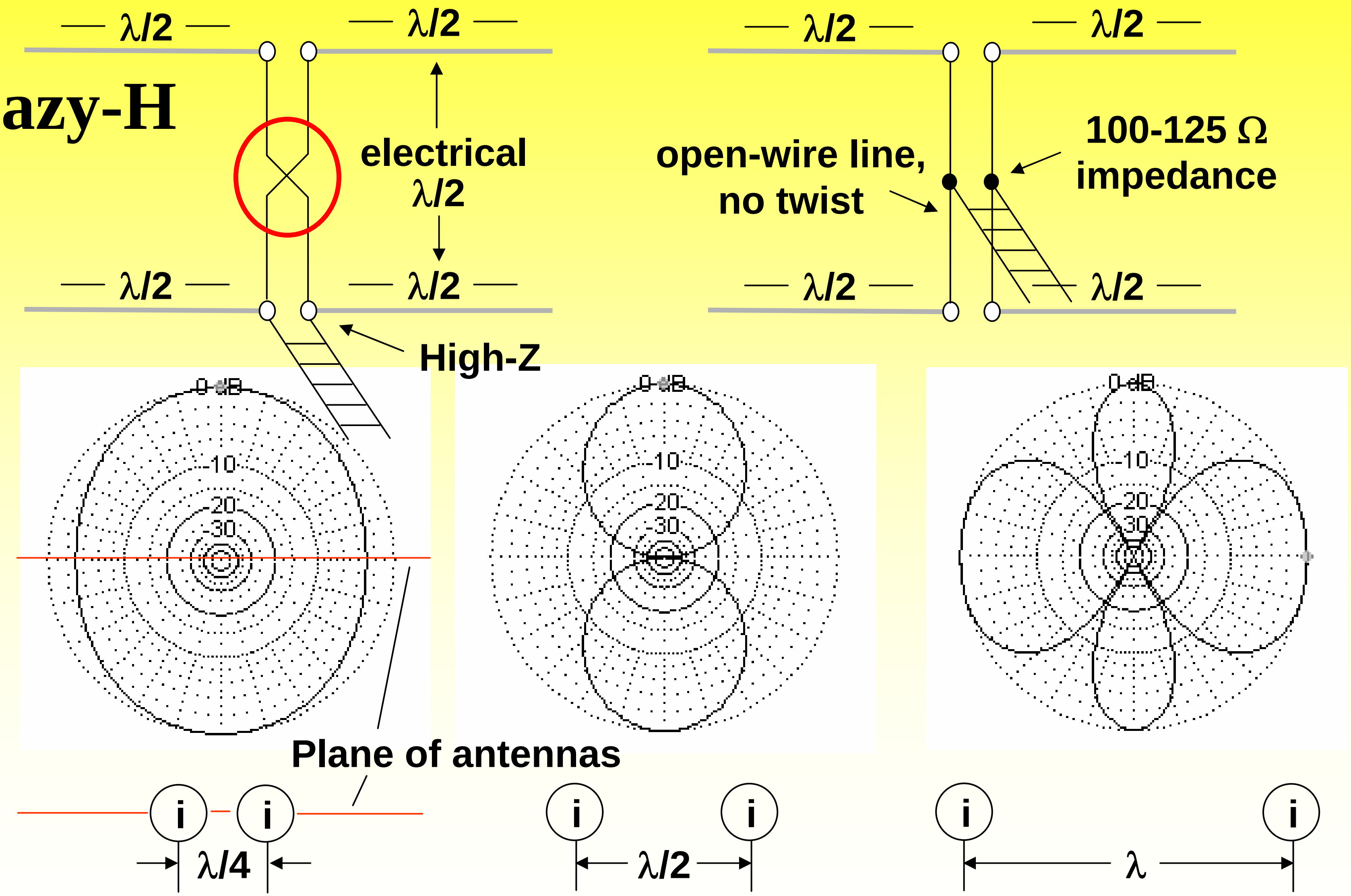
Phased Arrays - 2

- The original beam antennas
- Most constructed from $\lambda/2$ dipoles or $\lambda/4$ ground-planes
- Array plane can be vertical or horizontal
- Symmetrical arrays (including feeds) have symmetric patterns

Phased Arrays - 3

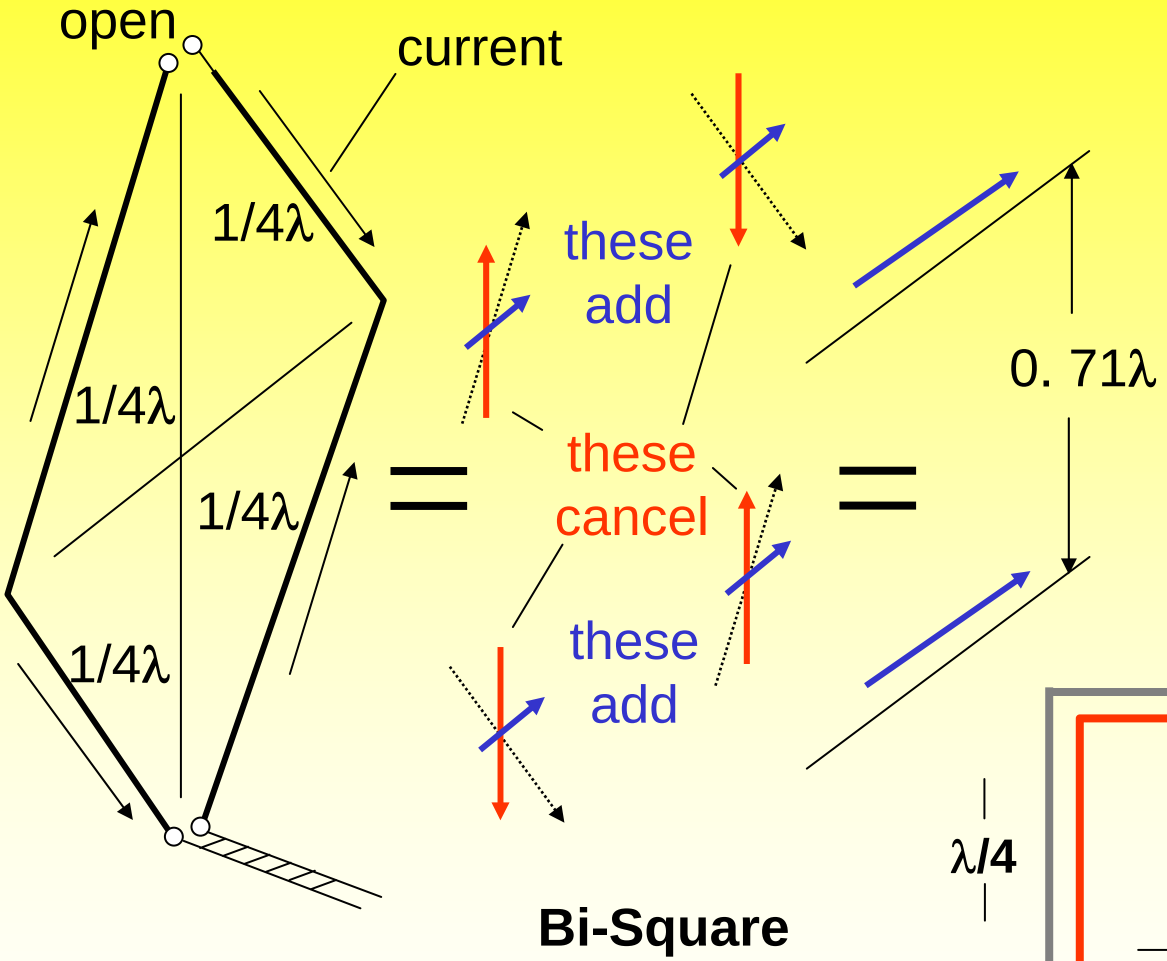
- Common Broadside Arrays
  - Lazy-H (two dipoles, in phase, vertical plane)
  - Half-square (two vertical elements)
  - Bi-square (like a Lazy-H, but one support)
- Common End-Fire Arrays
  - W8JK (two dipoles, out-of-phase, hor. plane)
  - Two-vertical array (switchable array)

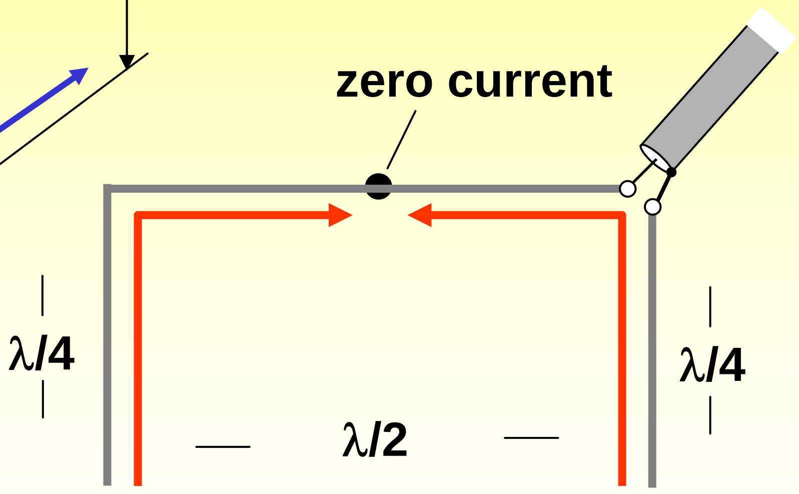
Phased Arrays - 4



Lazy-H

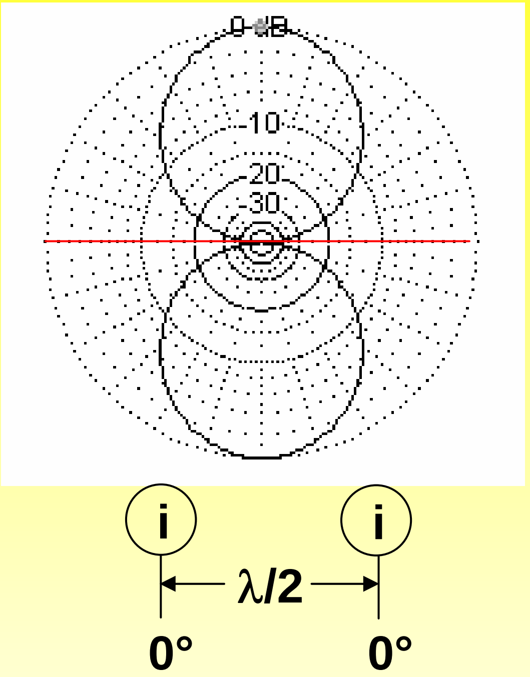
Phased Arrays - 5

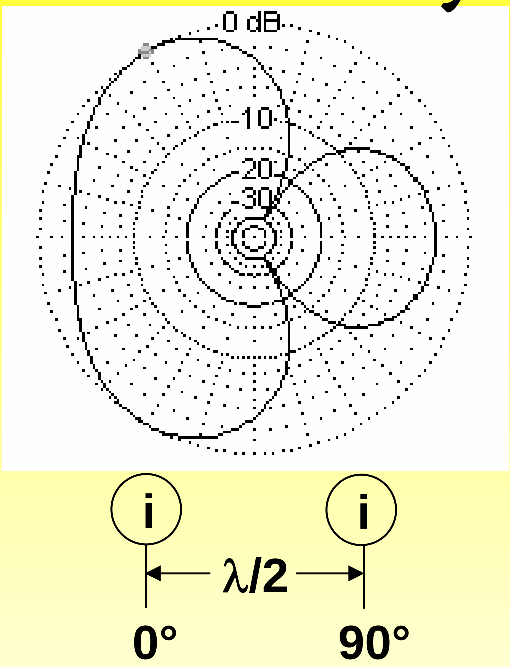


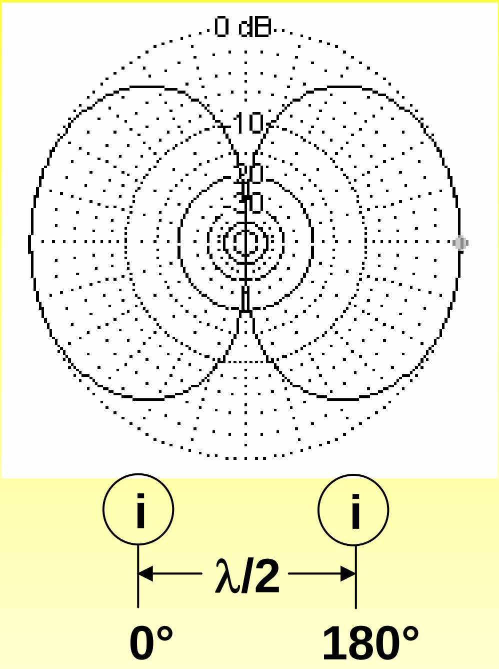


Half-Square

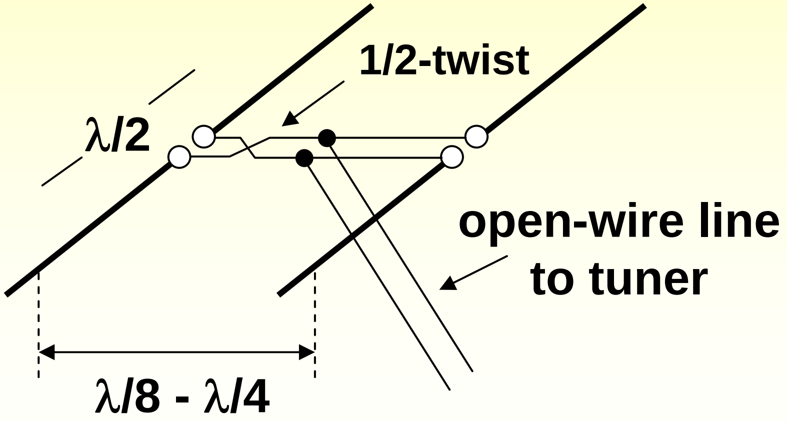
Phased Arrays - 6



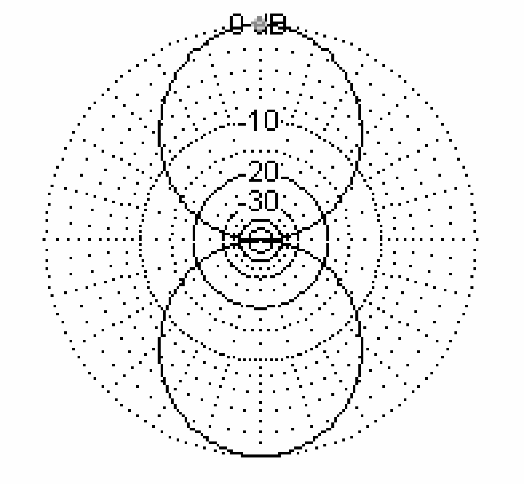


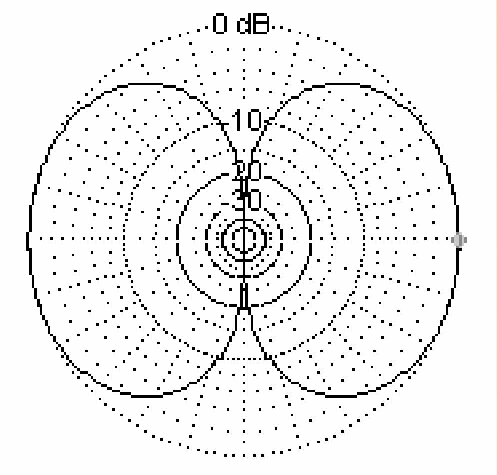


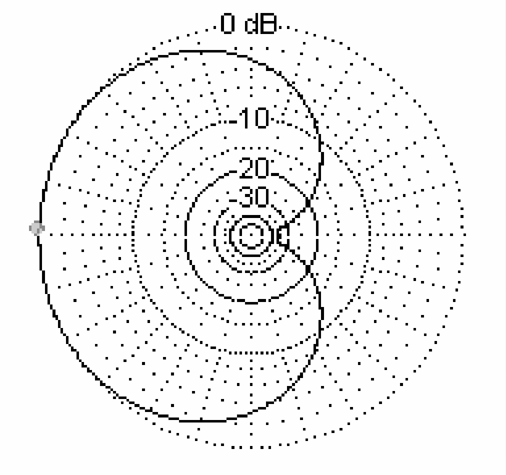
W8JK Array

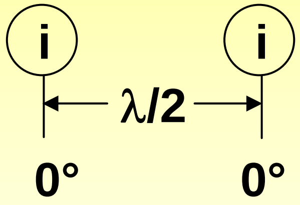


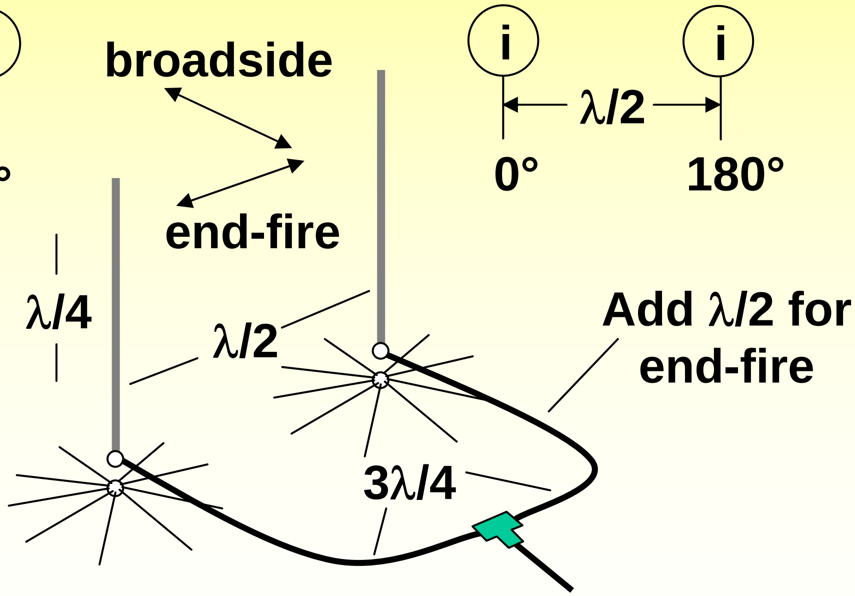
Phased Arrays - 7

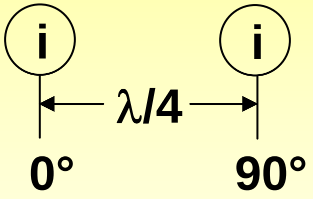












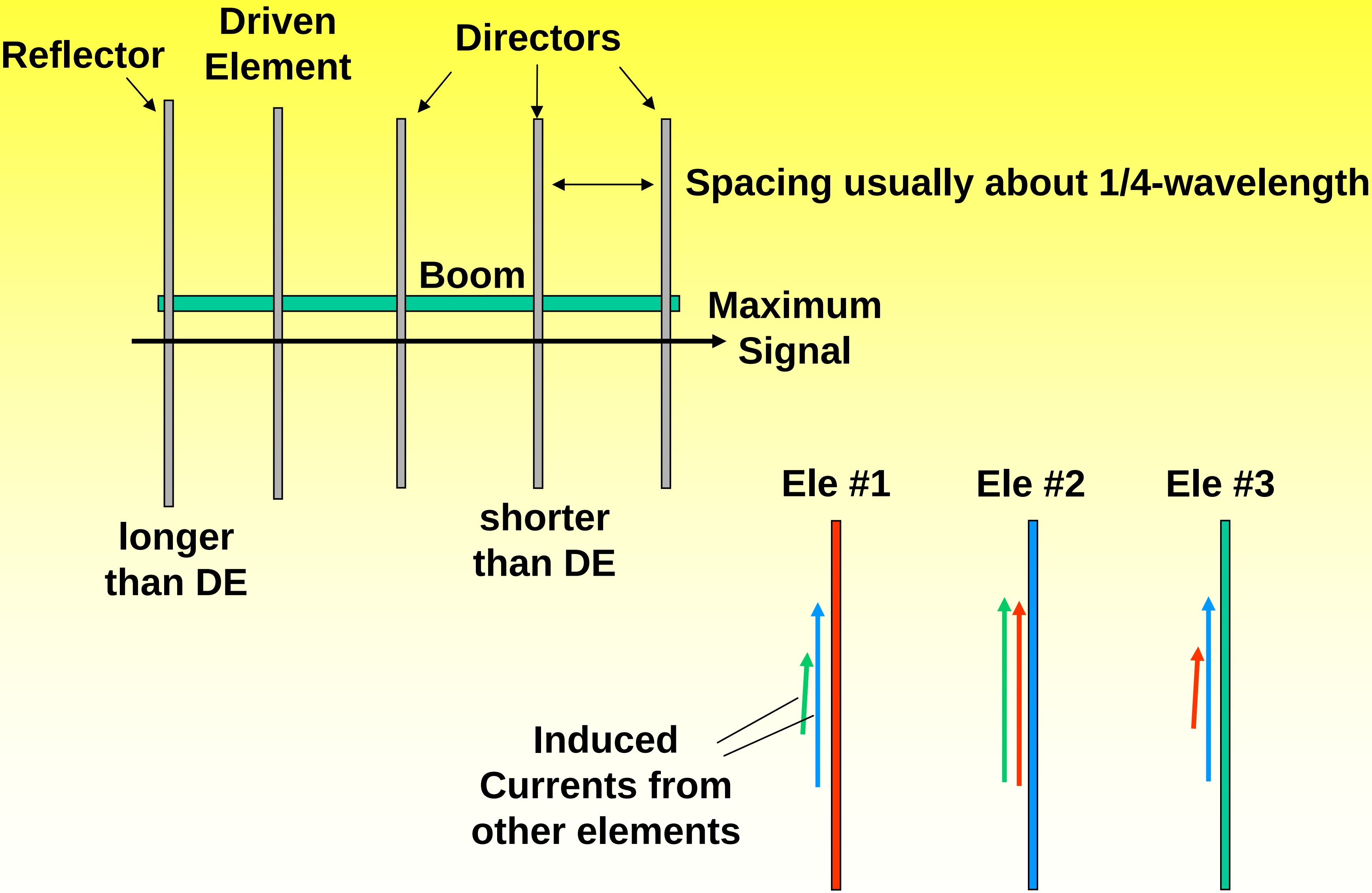
Cardioid Pattern

QUESTIONS??

Beam Antennas - 1

- Most accurately called *parasitic arrays*
  - non-driven elements that re-radiate energy to form the pattern are *parasitic elements*
- Usually refers to *Yagi-Uda arrays*
- Length and spacing of the elements determines the phase of the re-radiated signals

Beam Antennas - 2



Reflector

Driven Element

Directors

Spacing usually about 1/4-wavelength

Boom

Maximum Signal

longer than DE

shorter than DE

Ele #1

Ele #2

Ele #3

Induced Currents from other elements

Beam Antennas - 3

- Driven element (resonant)
  - Current & voltage in-phase
- Reflector (longer than resonant)
  - Inductive, current lags 90°
- Director (shorter than resonant)
  - Capacitive, current leads 90°
- Reradiation
  - 180° out of phase with inducing field

Beam Antennas - 4

- To the front:

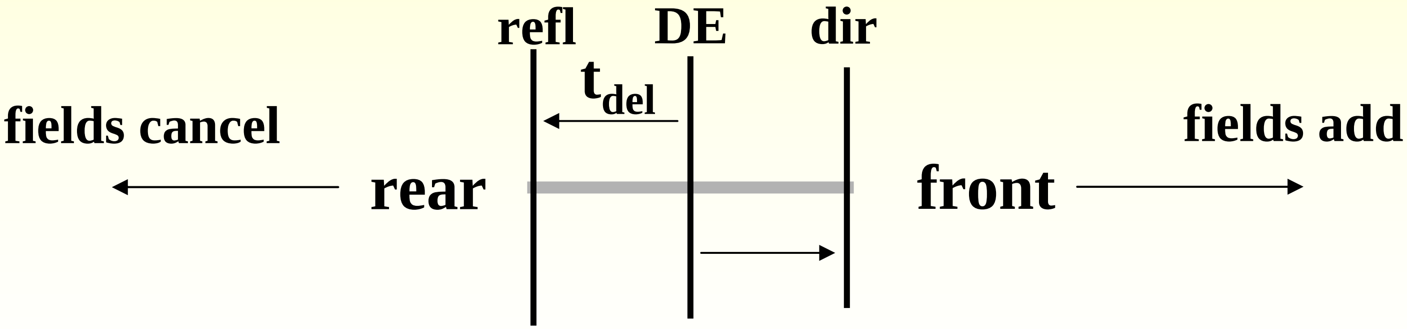
  Add to 180°

  - 0° at DE + travel delay (t_{del}) + director lead + re-radiation (180°) = 360° for reinforcement

- To the rear:

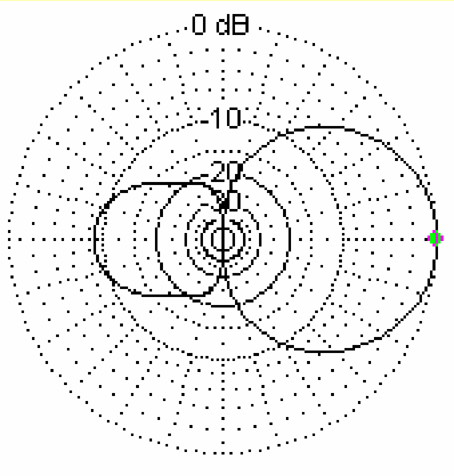
  Cancel out

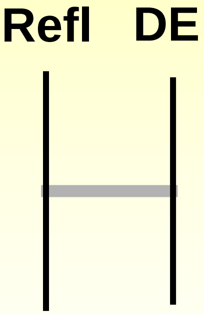
  - 0° at DE + travel delay - reflector lag + re-radiation (180°) = 180° for cancellation



Beam Antennas - 5

Reflector & Driven Element (preferred)





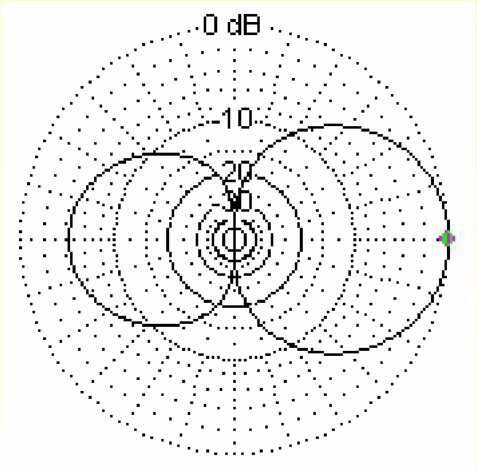
2-element Yagi

4.3 dBd

8.6 dB F/B

BW 69°

Driven Element & Director

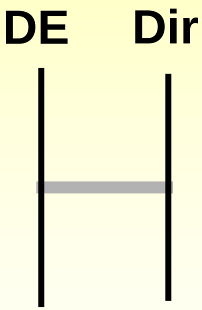


2-element Yagi

3.1 dBd

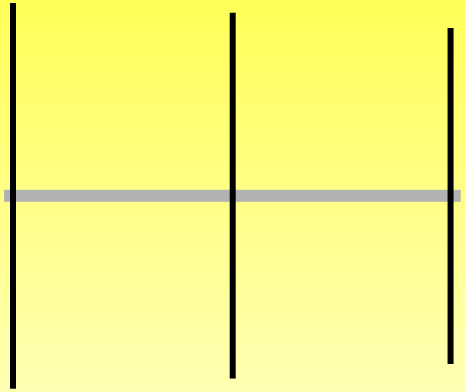
4.4 dB F/B

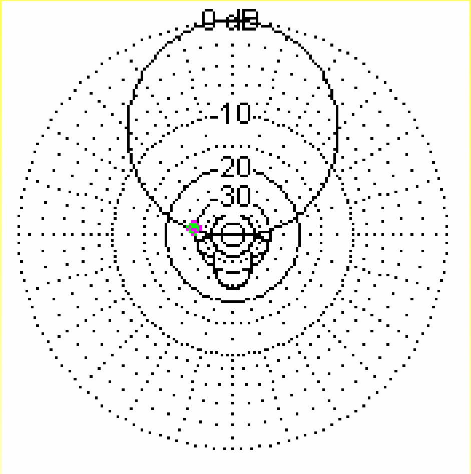
BW 71°



dBd = gain over a dipole

Beam Antennas - 6



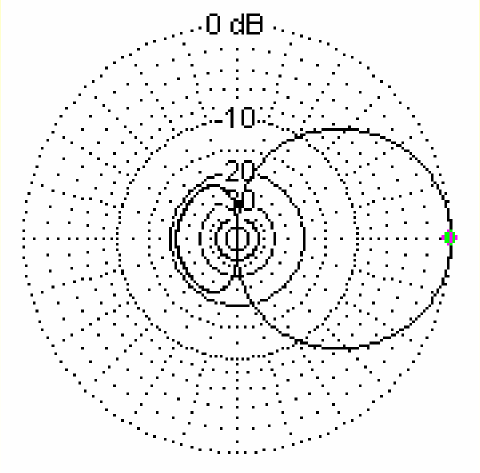


4-element Yagi

5.9 dBd

24 dB F/B

BW 63°

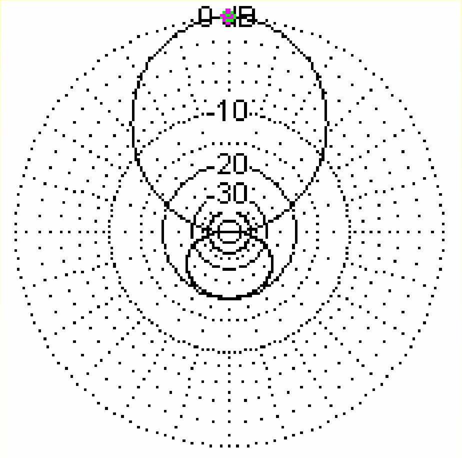


3-element Yagi

4.9 dBd

21 dB F/B

BW 61°



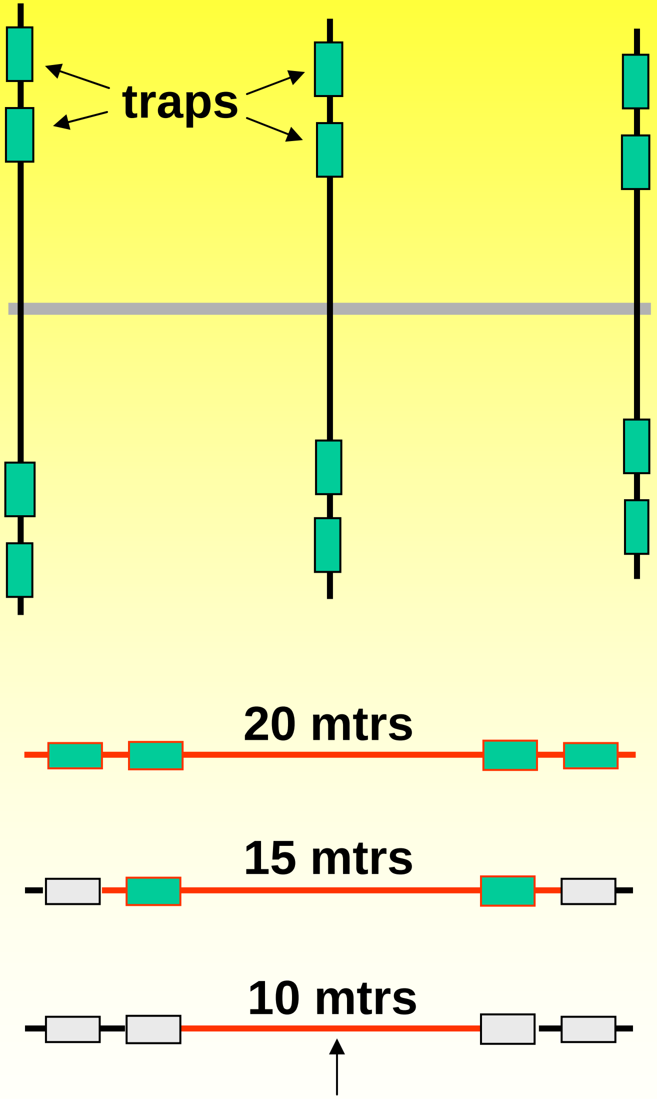
5-element Yagi

7.2 dBd

20 dB F/B

BW 57°

Beam Antennas - 7



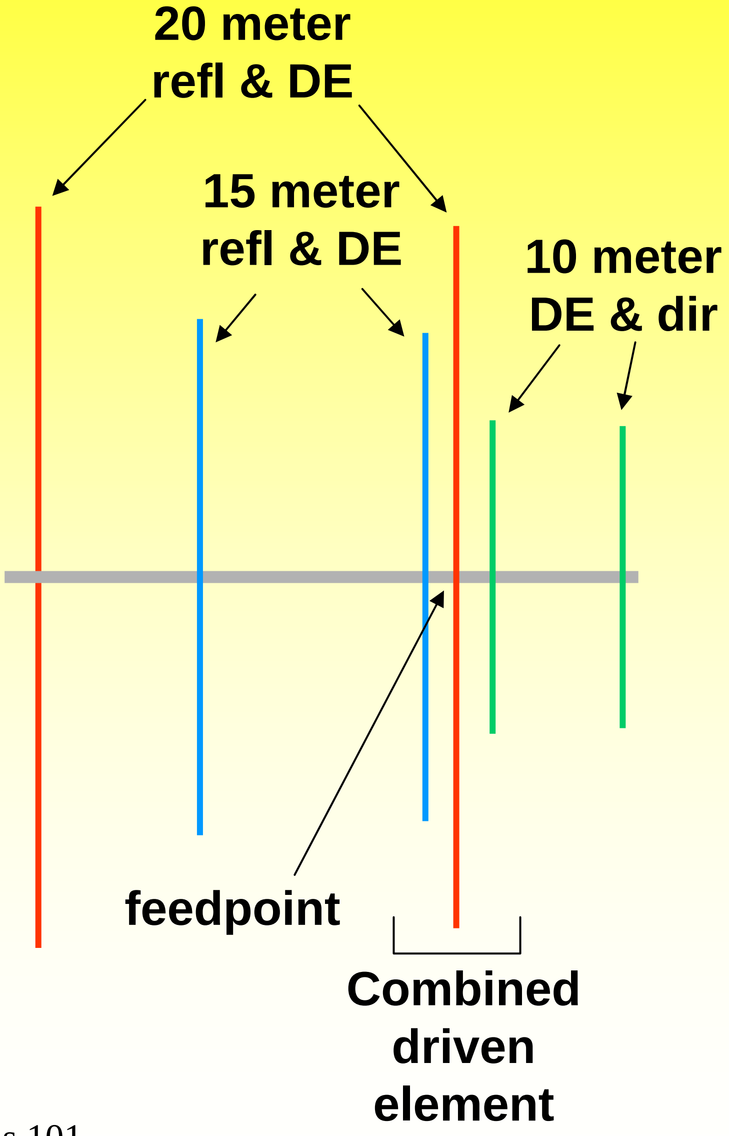
traps

20 mtrs

15 mtrs

10 mtrs

Active section



20 meter refl & DE

15 meter refl & DE

10 meter DE & dir

feedpoint

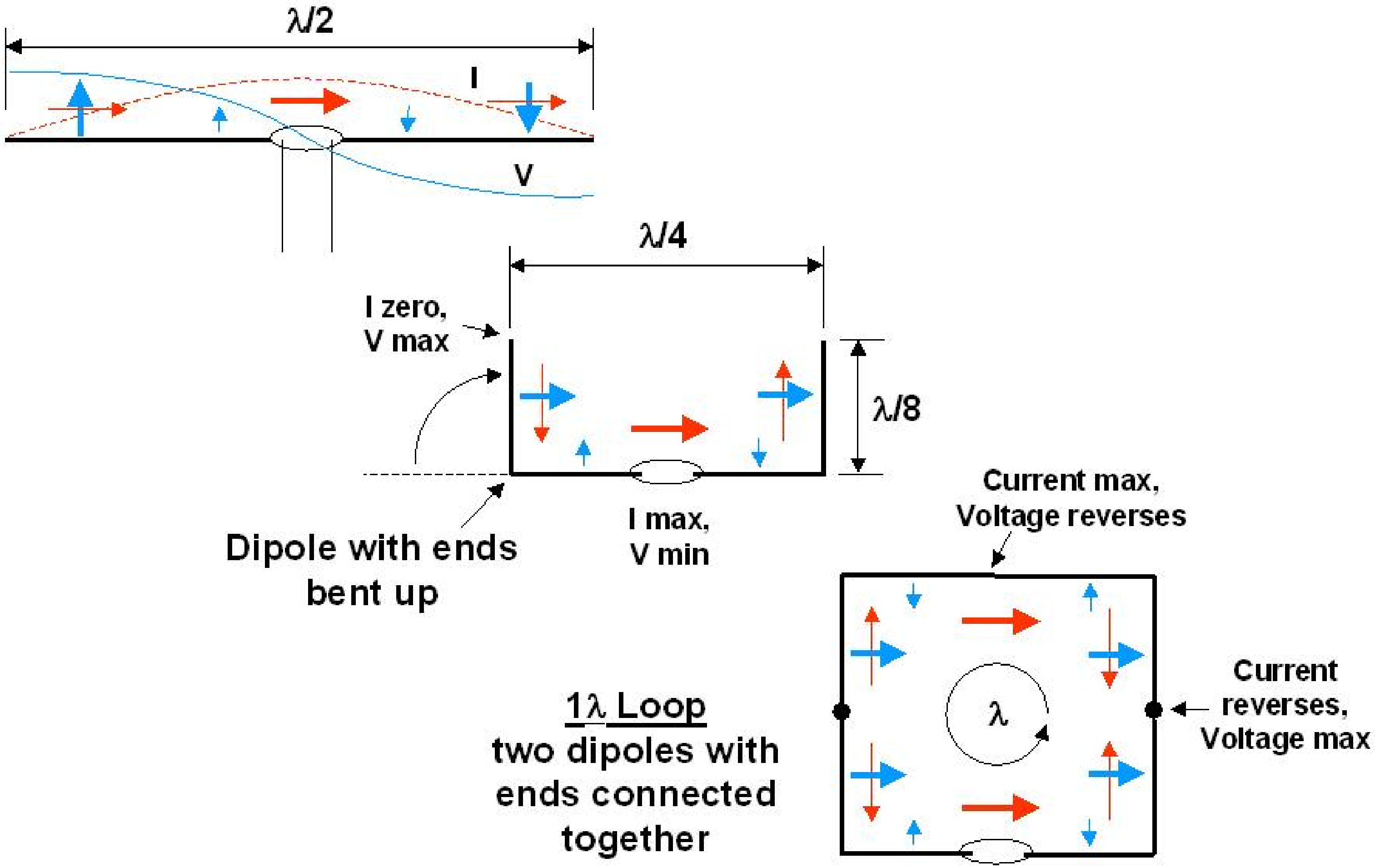
Combined driven element

QUESTIONS??

Loop Antennas - 1

- Take advantage of repeating current and voltage patterns
- Arrange antenna currents by…
  - Folding or bending the loop
  - Moving the feedpoint
- Loops have better bandwidth than parasitic and phased arrays

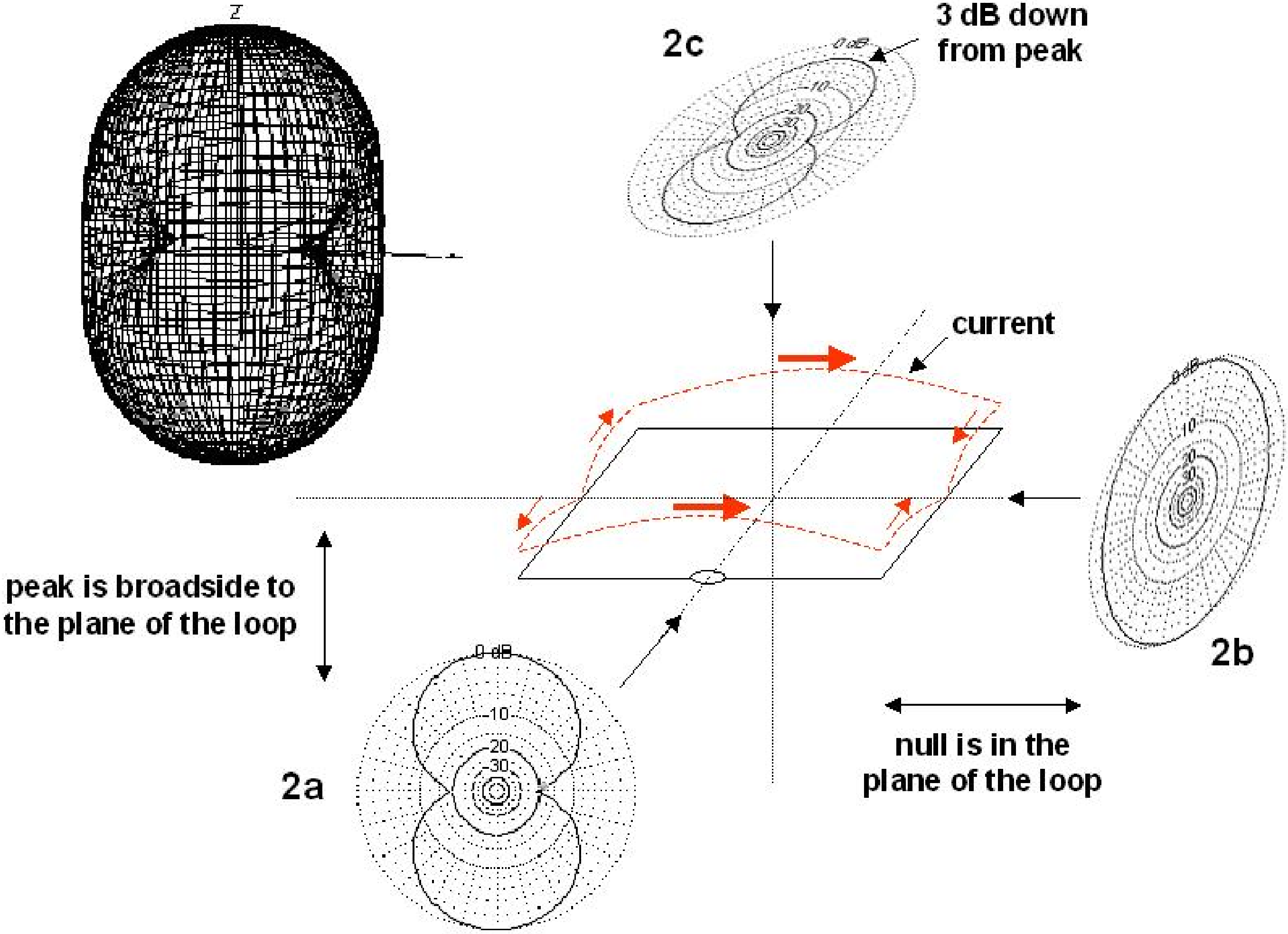
Loop Antennas - 2



Loop Antennas - 3

- 1λ loops can be used as array elements
  - Quads and Quagis
- Polarization and pattern are controlled by feedpoint placement
- Multiple-λ loops develop gain in the plane of the loop
  - Rhombics and Vee antennas

Loop Antennas - 4



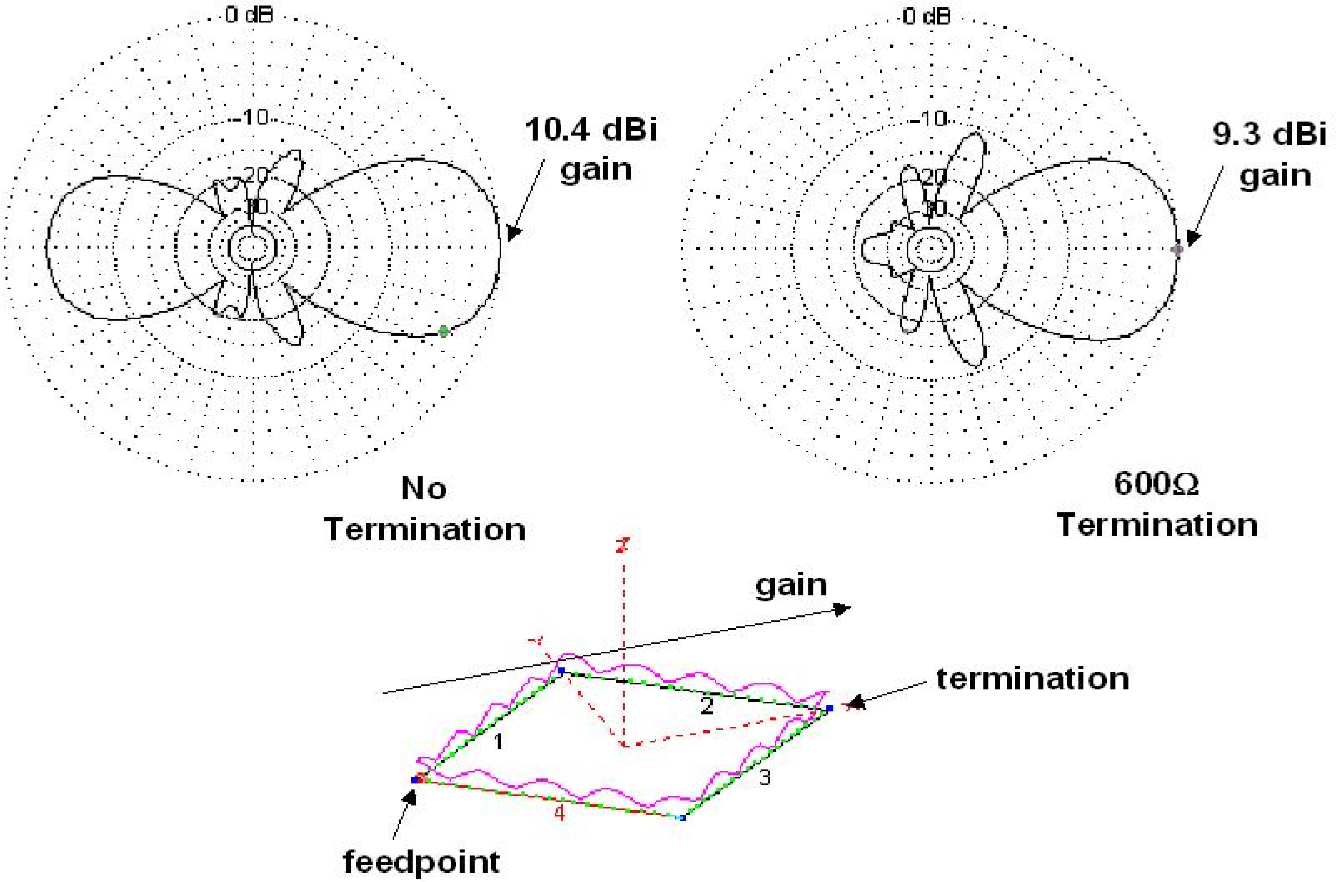
3 dB down from peak

current

peak is broadside to the plane of the loop

null is in the plane of the loop

Loop Antennas - 5



Rhombics

QUESTIONS??

Useful References and Books

- ARRL Publications
  - *Antenna Book*
  - *Compendium* and *Classics* series
- RSGB Publications
  - *Practical Wire Antennas* and *HF Antennas for all Locations*
- WorldRadio
  - *Aerials I, II, & III* by Kurt N. Sterba

Useful On-Line References

- ARRL Technical Information Service
- AC6V.com (and other portal type sites)
- L.B. Cebik's Web site - www.cebik.com
- Antennas and TowerTalk reflectors at www.contesting.com

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